

# **MISSOURI DEPARTMENT OF NATURAL RESOURCES**



## **CLEANUP LEVELS FOR MISSOURI (CALM) Appendix C**

### **Tier 2 Soil and Groundwater Cleanup Levels**

**Division of Air and Land Protection  
Hazardous Waste Program**

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# **CLEANUP LEVELS FOR MISSOURI (CALM)**

## **APPENDIX C - TIER 2 CLEANUP LEVELS**

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## TABLE OF CONTENTS

1. INTRODUCTION.....	C1
1.1 Tier 2 Evaluation.....	C1
1.2 Notification and Approval.....	C1
2. PROCESS FOR DETERMINING TIER 2 SOIL CLEANUP (STARC) VALUES .....	C2
2.1 Use of Background Concentrations of Contaminants.....	C2
2.2 Modification of Tier 1 Formula Defaults .....	C3
A. Parameters Which May Be Modified.....	C3
B. Requirement for Use of Actual Field Data.....	C5
2.3 Adjustment of $K_d$ for ionizable organics and metals based on soil pH.....	C5
2.4 Elimination of Pathways.....	C5
2.5 Partitioning of Site into Zones with Varying Exposure Scenarios.....	C6
2.6 Distant Point of Compliance for Leaching to Groundwater Pathway.....	C6
2.7 Use of Laboratory Leaching Test Data in Lieu of $C_{LEACH}$ .....	C8
2.8 Contaminant Mass Limitations.....	C8
2.9 Calculation of Site-Specific Dilution-Attenuation Factor (DF).....	C9
2.10 Use of an Alternate Q/C Value.....	C9
2.11 Tier 2 Cleanup Levels for Contaminants with Alternately Derived Tier 1 STARC Values.....	C9
A. Arsenic .....	C9
B. Chromium.....	C10
C. Copper.....	C10
D. Lead.....	C11
E. Methyl Tertiary Butyl Ether.....	C11
F. Polychlorinated Biphenyls.....	C11
G. Polynuclear Aromatic Hydrocarbons.....	C13
H. Total Petroleum Hydrocarbons.....	C13
3. PROCESS FOR DETERMINING TIER 2 GROUNDWATER CLEANUP (GTARC) VALUES.....	C13

## LIST OF TABLES

Table C1: Site-Specific Variables Which May Be Measured In The Field.....	C3
Table C2: Calculated Values Subject to Change With the Use of Site-Specific Inputs.....	C4
Table C3: Chromium Soil Target Concentrations.....	C10
Table C4: PCB Soil Target Concentrations.....	C11
Table C5: Degree of Chlorination for Aroclor Mixtures .....	C12
Table C6: Relative Potency Factors for Polynuclear Aromatic Hydrocarbons.....	C13



## 1. INTRODUCTION

Tier 2 is designed to provide flexibility in determining cleanup standards by allowing the use of site-specific data in place of the default assumptions made in Tier 1. It is an intermediate step between lookup tables based on assumptions for site conditions and complex contaminant transport modeling such as that used in Tier 3. A variety of parameters used in the soil target equations may be modified using actual field data from the site. Site-specific parameters may be used at the discretion of the user. However, in some cases it may be required by the department.

In addition to modifying equation parameters, several other actions are possible at Tier 2 which may affect the remediation or cleanup targets. These include: the use of background concentrations, use of engineering controls to change the exposure scenario, and others.

### 1.1 Tier 2 Evaluation

The following site-specific features may be considered in a Tier 2 evaluation. Any or all of these considerations may allow for adjustment of cleanup target concentrations. Refer to Section 2 of this appendix for a detailed discussion of each item.

Site-Specific Features for Tier 2 Evaluation
<ul style="list-style-type: none"><li>▶ Use of background concentrations of the chemical(s) of concern;</li><li>▶ Modification of assumptions made for various parameters used in the Tier 1 calculations using actual site data (e.g., source size, hydraulic conductivity, etc.);</li><li>▶ Adjustment of <math>K_d</math> for ionizable organics and metals based on soil pH;</li><li>▶ Consideration of site conditions or feasible engineering controls which may reduce or eliminate any of the exposure pathways considered in tier I (ingestion/dermal absorption/inhalation and leaching to groundwater);</li><li>▶ Evaluation of whether the site is large enough, and displays characteristics which are disparate enough, to justify partitioning into zones which might have different risk exposure scenarios or exposure pathways;</li><li>▶ Use of distant point of compliance for determining soil target concentrations for the leaching to groundwater pathway;</li><li>▶ Use of laboratory soil leaching data (TCLP or SPLP) in lieu of <math>C_{LEACH}</math> values</li><li>▶ Consideration of contaminant mass limitations and;</li></ul>
▶ Calculation of new dilution factor (DF) for $C_{LEACH}$ based on site-specific parameters.

### 1.2 Notification and Approval

If Tier 2 calculations will be used at a site, the department must be notified in writing of the intent to go from Tier 1 to Tier 2. The notification should include a description of the parameters measured onsite, the results obtained, and justification for using the site-specific



data. Although prior approval is not required for the use of Tier 2, the department must concur with the results obtained and must approve the Tier 2 soil target concentrations prior to remediation (if remediation is required) or issuance of a NFAL.

## **2. PROCESS FOR DETERMINING TIER 2 SOIL CLEANUP (STARC) VALUES**

### **2.1 Use of Background Concentrations of Contaminants**

Background soil or ground water concentrations may be considered when comparing the Tier 2 TARC levels to site concentrations. The following conditions must be met in order to use background concentrations as cleanup targets:

1. Naturally occurring background contaminant levels in native media are above the Appendix B, Table B1 STARC values.
2. The contaminant must occur at background levels which are naturally occurring (non-anthropogenic<sup>1</sup>).
3. A sampling plan for the determination of background soil levels should be approved by the department prior to background sampling. If the number of samples to be collected is sufficient for the use of statistical analysis, a plan for such analysis should be submitted to the department for approval.
4. Background samples must not be collected from areas where other anthropogenic sources may have contributed the same contaminants as those encountered at the site under investigation.
5. Samples should be collected from geologic strata and/or water-bearing formations similar to those taken from the contaminated site using similar sampling protocols.
6. If ground water is to be sampled for background contaminant concentrations with the intention of using background values in lieu of GTARC cleanup standards, it must be shown that the contaminants originate offsite.

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<sup>1</sup> For example, the non-anthropogenic (natural) background levels of arsenic in Missouri are typically in the range of the residential use (Scenario A) soil target concentrations. If natural background levels at or near a site were determined to be consistently at or slightly above the health-based STARC values, background levels could be used as soil target concentrations. In contrast, a contaminated site located in an area widely contaminated with the same contaminant from historical industrial activity (such as a site near a historic lead smelter) would be subject to the STARC values because the surrounding background levels were the result of human activity and do not represent natural background.



## 2.2 Modification of Tier 1 Formula Defaults

### A. Parameters Which May Be Modified

Parameters that may be substituted with site-specific values for calculation of site-specific Tier 2 soil target concentrations are identified in the right-hand column of Appendix A, Table A2. These variables have been consolidated in Tables C1 and C2. Any or all of the values may be replaced with site-specific values for calculation of Tier 2 soil target concentrations, both  $C_{IDI}$  and  $C_{LEACH}$ .

**Table C1: Site-Specific Variables Which May Be Measured In The Field**

Variable	Description
$a_x$	Longitudinal dispersivity (cm) (dependent on x)
$a_y$	Transverse dispersivity (cm) (dependent on x)
$a_z$	Vertical dispersivity (cm) (dependent on x)
$d_a$	Aquifer thickness (m)
$dh/dx$	Hydraulic gradient (m/m)
$d_s$	Average soil contaminant source depth (m)
$f_{oc}$	Fraction of organic carbon in soil (unitless)
$\lambda$	First order contaminant degradation constant (days)
$I$	Infiltration rate (m/year)
$K$	Hydraulic conductivity (m/year)
$K_d$	Soil-water partition coefficient (L/kg) (for metals and ionizable organics only)
$L$	Soil contaminant source length parallel to groundwater flow (m)
$n$	Total soil porosity (Lpore/Lsoil)
$D_b$	Soil dry bulk density (kg/L)
$S_h$	Soil contaminant source width perpendicular to groundwater flow in the <i>horizontal</i> plane (m)
$S_v$	Soil contaminant source width perpendicular to groundwater flow in the <i>vertical</i> plane (m)
$0_w$	Water-filled soil porosity (Lwater/Lsoil)
$0_a$	Air-filled soil porosity (Lair/Lsoil)
$U_m$	Mean annual wind speed (m/sec)
$U_t$	Equivalent threshold value of windspeed at 7m (m/sec)
$V$	Fraction of vegetative cover at the site (unitless)
$x$	Centerline distance from downgradient edge of soil source to point of compliance, in the direction of groundwater flow (m)


**Table C2: Calculated Values Subject to Change With the Use of Site-Specific Inputs**

Parameter	Description
$C_{DER}$	Soil target concentration for the dermal contact pathway (mg/kg)
$C_{ID,I}$	Soil target concentration for ingestion/dermal contact/inhalation pathway (mg/kg)
$C_{ING}$	Soil target concentration for the soil ingestion pathway (mg/kg)
$C_{INH}$	Soil target concentration for the inhalation pathway (mg/kg)
$C_{leach}$	Soil target concentration for the leaching to groundwater pathway (mg/kg)
$C_{leach,ml}$	Mass-limited soil target concentration for the leaching to groundwater pathway (mg/kg)
$C_{sat}$	Soil saturation concentration (mg/kg)
$C_w$	Calculated contaminant concentration in groundwater directly beneath the soil source for when the groundwater point of compliance is at the source (mg/l).
$Cw_{attn}$	Calculated contaminant concentration in groundwater directly beneath the soil source form when the groundwater point of compliance is not at the source (mg/l).
$C_x/C_{source}$	Groundwater contaminant attenuation factor (unitless)
$d$	Depth of mixing zone (m)
$D_{app}$	Apparent diffusivity (cm <sup>2</sup> /sec)
$DF$	Dilution factor (unitless) (all supporting variables must be detected)
$F(x)$	Function dependent on $U_m/U_t$ , derived using Cowherd et al. (1985) (unitless)
$K_d$	Soil-water partition coefficient (L/kg)
$PEF$	Particulate emission factor (m <sup>3</sup> /kg)
$Q/C$	Inverse mean contaminant concentration at the center of a square source (g/m <sup>2</sup> -s per kg/m <sup>3</sup> )
$U$	Linear average groundwater (or seepage) velocity (cm/day)
$VF$	Volatilization factor (m <sup>3</sup> /kg)

Determination of all the parameters may not be necessary for every site. Site specific values may be used for any number of parameters, with Tier 1 default values used for the remaining parameters. The number of site-specific values used will be in accordance with



the desired effort and cost the user wishes to expend to obtain the site-specific information.

### **B. Requirement for Use of Actual Field Data**

In general, deviations from the Tier 1 assumptions must be based on actual field data from the immediate area of the site. For example, if alternate hydraulic conductivity and groundwater gradient values are used, they must be determined by installation of monitoring wells and aquifer testing at the site or on nearby sites, and cannot be based on generic regional geological profile information.

However, local or regional average data can be used for some parameters, such as average wind speed. It should be noted that some physical properties vary seasonally (e.g. water and air filled soil porosity). Therefore, it may be necessary to conduct multiple sampling efforts in order to adequately characterize these properties.

## **2.3 Adjustment of $K_d$ for ionizable organics and metals based on soil pH**

Ionizable organics and metals may exist in different forms depending on pH and will have varying adsorptive properties in soils at different pH values. For these compounds, site-specific  $K_d$  or  $K_{oc}$  values may be used. Determination of the site-specific values will require measurement of the site soil pH. The soil pH should be measured at the same location and depth as the contaminants of concern.  $K_d$  and  $K_{oc}$  values for various pH values may be obtained from EPA's Soil Screening Guidance User's Guide (1996), or other approved sources.

The occurrence of heavy metals in various oxidation states and as salts of varying solubility can lead to widely varying behavior of the same metals at different sites. This is one reason why standard  $C_{LEACH}$  values for contaminants such as lead, chromium and mercury are not listed in the Tier 1 STARC tables. These types of contaminants must be evaluated on a site-specific basis until complete data on the most commonly occurring forms is obtained.

## **2.4 Elimination of Pathways**

The progression to Tier 2 may include or be a result of the elimination of exposure pathways at the site. For example, a remedial action may eliminate direct contact with contaminated soil and thus eliminate the ingestion and dermal exposure pathways. The IDI equation, which includes these pathways along with inhalation of vapors and particulates, would no longer be strictly applicable to the site. However, the remaining pathways should still be considered. To calculate  $C_{IDI}$  values for remaining pathways when one or more have been eliminated, the "pathway terms" (Ingestion, Inhalation, Dermal) in Equations 1 and 2 (Appendix A, Table A1) should be set to zero for the pathways eliminated.



## 2.5 Partitioning of Site into Zones with Varying Exposure Scenarios

Larger sites with different land use scenarios in different portions of the site may be partitioned into areas with varying soil target concentrations. An example might be a large manufacturing facility with a commercial or retail development planned for part of the site. The industrial area might be classified as Scenario C, while the commercial portion of the site would be subject to Scenario B.

Land use scenarios for each portion of the site should be determined using the land use scenario flowchart (CALM Figure 2). Engineering or institutional controls may be required to control access between the parts of the site, and/or to ensure adherence to the land use restrictions if any portion of the site is not cleaned up to Scenario A STARC and/or GTARC.

Proposals for partitioning of larger sites will be considered on a site-specific basis. The department will require that a professional land survey be performed to clearly delineate the partitioned zones. Partitioning is expected to be used for larger sites with clear future use plans, and is not intended to be used at small sites in order to avoid remediation of hot spots or contaminant sources by partitioning very small areas.

## 2.6 Distant Point of Compliance for Leaching to Groundwater Pathway

Under certain conditions, it is acceptable to move the point of compliance (POC) from the contaminant source (as required in Tier 1), to some distant point, typically a property boundary or environmental receptor such as a water body. The point of compliance may not be moved farther from the site than the property boundary.

In Tier 1, it is assumed that the point of compliance for both soil and groundwater target concentrations is at the contaminant source. The Tier 1 soil target concentration for the leaching to groundwater pathway,  $C_{LEACH}$ , represents a contaminant concentration that was calculated to prevent contaminants from leaching into groundwater at the source location at levels above the groundwater target concentration (GTARC). For simplicity as well as conservatism in calculating the Tier 1  $C_{LEACH}$  values, it is assumed that there is no degradation, dispersion, or loss of contaminant by sorption, either in the soil column or in the aquifer. Adsorption to the soil matrix, however, is accounted for by the inclusion of  $K_d$ .

When the point of compliance is at the source, the  $C_{LEACH}$  equation includes the assumption that all of the contamination present will leach into a specific volume of groundwater over a specified period of time equal to the exposure duration (ED). At Tier 2, if the point of compliance is moved away from the source (i.e., to the property boundary), an added step



must be included in this theoretical leaching process to account for the advection, dispersion and degradation of the contaminant within the saturated zone as the plume moves from the source area to the point of compliance. Formula 18, Appendix A, accounts for this extra step in the derivation of the soil contaminant target concentration,  $C_{LEACH}$ , resulting in a contaminant concentration  $Cw_{attn}$ , that never exceeds the groundwater target concentration (GTARC) at the distant point of compliance. The supporting equations (formulas 13-16, Appendix A) include an advection/dispersion/degradation factor ( $C_x/C_{source}$ ) to facilitate this calculation.

Groundwater contamination does not have to exist at the site for these equations to be applicable. The soil target concentration,  $C_{LEACH}$ , is intended to protect against future groundwater contamination and therefore should be used at the site regardless of groundwater contamination.

The following requirements must be met in order to use a distant point of compliance for leaching in Tier 2:

1. Subsurface conditions at the site are poorly represented by the assumptions inherent in the advection/dispersion formula found in Appendix A (the default variable values are summarized in Table A2). Thorough subsurface characterization must be performed on the site to provide confidence in this approach. If complex hydrogeologic features are present, such as multiple irregular strata or karst conditions, these equations cannot be used. These conditions would require the use of more sophisticated contaminant transport models as described in Appendix D.
2. Institutional controls (i.e., restrictive covenants) are placed in the chain of title to prevent groundwater use at the site. Use of the attenuation factor to calculate site-specific  $C_{LEACH}$  values for a distant POC in Tier 2 requires an institutional control prohibiting use of the aquifer at the site for any purpose for which contaminants could exceed the groundwater standards (GTARC). This is because the assumptions made in the advection/dispersion equation allow for groundwater contaminant concentrations beneath the source which are higher than GTARC. See Appendix E for further information on institutional controls.
3. A groundwater monitoring plan must be implemented. Monitoring is used to verify the predictions of the model; if predicted leaching does not occur, or previously detected groundwater contaminants decrease to levels consistently below GTARC, the groundwater use restriction may be withdrawn with the consent of the department.



## 2.7 Use of Laboratory Leaching Test Data in Lieu of $C_{LEACH}$

In lieu of the above method, actual data obtained by analysis of site soils using the synthetic precipitation leaching procedure (SPLP), EPA method 1312, may be utilized to analyze leaching potential. Since laboratory leach testing results represent an estimate of soil leachate concentrations, a site-specific laboratory leach testing value can also be used as a starting point for determining the potential for groundwater contaminants to exceed GTARC at the point of compliance. For sites where the POC is at the source, if the leachate concentration does not exceed GTARC, leaching to groundwater will not be considered an important exposure pathway. If a distant POC has been approved, and the laboratory leachate testing result multiplied by the  $C_x/C_{source}$  term (Equation 14, Appendix A) does not exceed GTARC, the contaminants are not expected to leach above acceptable limits, and leaching to groundwater will not be considered an important exposure pathway.

## 2.8 Contaminant Mass Limitations

Calculation of soil targets for the leaching to groundwater pathway requires input parameters for the volume of contaminated soil. These parameters are:

- L Length of contaminant source parallel to groundwater flow (m)
- $d_s$  Average contaminant source depth (m) ( i.e., depth of contaminated soil layer)

For Tier 1, an “infinite source” model has been used for  $C_{LEACH}$ . That is, the calculations do not take into account the total mass of the contaminants present. For some combinations of source size, soil conditions, and contaminant properties, the infinite source assumption may result in the calculation of  $C_{LEACH}$  values which violate mass-balance principles. For example, the  $C_{LEACH}$  value calculated for a site with a small contamination source and/or high contaminant solubility and volatility, may indicate that more mass of contaminant is released from the soil than was present to begin with. In order to minimize mass-balance principle violations, the mass of contaminant leached can be limited to the total mass of contaminant present in the soil. The formula used to calculate the mass-limited  $C_{LEACH}$  is found in Table A1 (Equations 16-18). It should be noted that the source area cancels out during derivation of this equation (see EPA Soil Screening Guidance). If a mass-limited  $C_{LEACH}$  value is calculated for the site, the cleanup level that applies is the larger of the infinite-source ( $C_{LEACH}$ ) and mass-limited ( $C_{LEACH,ml}$ ) values.

The mass-limit approach has the following advantages:

1. It corrects the possible mass-balance violation in the infinite-source  $C_{LEACH}$  calculation.
2. It does not require use of a complex finite-source model to calculate  $C_{LEACH}$ .
3. For small sites, although  $C_{LEACH,ml}$  is often higher than  $C_{LEACH}$ , it is still protective of human health and the environment, since it is based on the conservative assumption



that all of the contaminant will leach over the period of exposure.

4. It requires only simple calculations using input parameters that are already used to calculate the infinite-source  $C_{LEACH}$  values.

## 2.9 Calculation of Site-Specific Dilution-Attenuation Factor (DF)

A site-specific Dilution/Attenuation Factor (DF) may be calculated for the site in Tier 2. EPA's Soil Screening Guidance uses a default value of  $DF=20$  for calculation of soil target concentrations for the leaching to groundwater pathway, but does not specify default values for the individual parameters that appear in the DF formula. This approach has also been followed in CALM to calculate the Tier 1  $C_{LEACH}$  values. Therefore, if DF is to be recalculated based on site data for Tier 2, *all* the parameters that appear in the DF formula must be determined in the field. These include hydraulic conductivity (K), groundwater hydraulic gradient ( $dh/dx$ ), depth of contaminant source (d), annual water infiltration rate (I, may be obtained from regional data), source length parallel to groundwater flow (L), and aquifer thickness ( $d_a$ ). Substitution of some of the values but not others is not possible since there are no Tier 1 defaults for these individual parameters.

## 2.10 Use of an Alternate Q/C value

Dispersion analyses conducted by EPA using the Industrial Source Complex Model (ISC2) were used to generate Q/C values for a variety of meteorological conditions and site sizes. As discussed in Appendix B, the Tier 1 default value was selected based on a 0.5 acre site in Lincoln, Nebraska. At Tier 2, the user may select Q/C values determined by EPA based larger site sizes if applicable as follows.

	<u>1 Acre</u>	<u>2 Acre</u>	<u>5 Acre</u>	<u>10 Acre</u>	<u>30 Acre</u>
Q/C	71.47	63.22	54.47	48.89	41.65

## 2.11 Tier 2 Cleanup Levels for Contaminants with Alternately Derived Tier 1 STARC Values

Tier 1 cleanup values for several contaminants, as listed in Appendix B, Section 5, were determined by methods other than the standard methods used for the other contaminants in the TARC table as described in Appendix B. The available procedures for determining Tier 2 target concentrations for soil for these contaminants are discussed below.

### A. Arsenic

Comparison of site concentrations of arsenic (As) to local background concentrations may be particularly useful due to naturally high background arsenic concentrations in



Missouri. Background concentrations should be determined and used following the guidance in Section 2.1.

The Tier 1 arsenic values for land use scenarios A and B are based on non-cancer effects and are calculated using standard Tier 1 methods and models. Therefore, modifications to default formula parameters using site-specific data, such as soil properties, may be made the same as with other contaminants.

## B. Chromium

The values in the Tier 1 TARC table for chromium (Cr) are based on a weighted average of cleanup values for  $\text{Cr}^{+3}$  (90%) and  $\text{Cr}^{+6}$  (10%). At Tier 2, speciation analysis can be used to determine the concentration of trivalent and hexavalent chromium at the site. The following cleanup standards would then apply:

**Table C3. Chromium Soil Target Concentrations**

Species	Scenario A	Scenario B	Scenario C
$\text{Cr}^{+3}$	1400	1900	2900
$\text{Cr}^{+6}$	320	450	940

Given the general rarity of  $\text{Cr}^{+6}$  values above 10% of the total Cr in contaminated soils, it is unlikely that speciation analysis alone will result in a significant change in cleanup targets. However, the above values may be used if speciation analysis is performed. Note that these values are calculated using standard Tier 1 methods and models. Therefore, modifications to default formula parameters using site-specific data, such as soil properties, may be made the same as with other contaminants. If speciation analysis demonstrates the absence of hexavalent chromium at a given site, the leaching pathway will not be considered important for that site. For larger sites with numerous sample locations, selected samples may be speciated. Due to the variability between sites, this option will be evaluated and approved by the department on a site-specific basis.

## C. Copper

Modification of the Tier 1 values for copper (Cu) can be made similarly to most of the contaminants listed in the Tier 1 TARC table. The reference dose of 0.037 mg/kg/day for a 70 kg adult used in Tier 1 may be used for Tier 2 calculations.



## D. Lead

Calculations for lead (Pb) were done using EPA's Screening Level For Lead Program, Version 1.0 (also known as the Adult Lead Model and the Pregnant Worker Model), and the Integrated Exposure Uptake Biokinetic Model, IEUBK99D (USEPA 1994a). In some cases, the default values used for the model parameters, which are listed in Appendix B, Figure B3, may be modified using site-specific, technically supportable data. All modifications to these models require approval of both MDNR and MDOH.

## E. Methyl Tertiary Butyl Ether (MTBE)

Modifications to default formula parameters using site-specific data, such as soil properties, may be made the same as with other contaminants.

## F. Polychlorinated Biphenyls

PCB mixtures are highly complex and both physicochemical and toxicological data is incomplete on the various commercial products (e.g. Aroclors). Tier 1 values are based on the toxicity factors for Aroclor 1254, a mixture for which data is available and which is one of the more toxic Aroclors. The Tier 1 STARCs are therefore considered to be fairly conservative, and are calculated using standard Tier 1 methods and models found in Appendix A. Modifications to default formula parameters using site-specific data, such as soil properties, may be made the same as with other contaminants.

A second alternative method for determining site-specific cleanup levels for PCBs requires determining the actual Aroclor or Aroclor mixture present at the site. The toxicity of PCBs tends varies with chlorine number. With "fresh" PCB mixtures, toxicity values based on the degree of chlorination (e.g. percent monochlorinated, dichlorinated, etc.) are available and shown in Table C4.

Since the degree of chlorination for each of the commercially used Aroclor mixtures is known (see Table C5), the user may determine a cleanup target based on the PCB mixture(s) actually present at the site.

**Table C4. PCB Soil Target Concentrations**

Chlorination Level of Mixture	Scenario A	Scenario B	Scenario C
>50% mono-chloro PCBs	4.9 ppm	6.9 ppm	16 ppm
>50% mono- + di-chloro	2.5	3.5	10

**Table C4. PCB Soil Target Concentrations**

>50% mono- + di- + tri-chloro	1.2	1.8	5.0
>50% tetrachloro through decachloro	0.6	0.9	2.5

**Table C5. Degree of Chlorination for Aroclor Mixtures**

Aroclor Mixture	Degree of Chlorination (percent)							
	Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	≥ Octa
1221	51	32	11					
1232	31	24	28	12	4			
1242	3	13	38	30	22	4		
1016	1	20	57	21	1			
1248		2	18	40	36	4		
1254				11	49	34	6	
1260					12	38	41	9

However, PCBs found in soils may not correspond closely to a particular Aroclor due to weathering, or the presence of more than one similar Aroclor mixture. When these conditions occur, the user should conduct a congener-specific analysis, grouping the congeners into categories based on degree of chlorination, and then determine a site-specific cleanup target using Table C4 above. This method may involve a significantly higher analytical cost than Aroclor mixture identification.

A third method for determining site-specific cleanup levels for PCBs also involves using congener-specific analysis. This method is expected to be cost-effective only in rare cases due to the extremely time-consuming and expensive analytical techniques required. Congener-specific analysis may be performed on site samples to determine the most prevalent individual PCB congeners. This set of congeners can then be used as “markers” or representative congeners. Toxicity and chemical property data may then be obtained for the ten to twenty most abundant congeners and used to calculate individual STARC values for those congeners using the standard Tier 1 formulas. The remaining congeners can be assumed to behave similarly to the representative set, and the cleanup requirements are based on the calculated values for the representative set.



The alternative methods described above may be combined with the use of site-specific hydrogeological data. The department should be consulted for toxicological parameters (i.e. slope factors) to facilitate those calculations.

### G. Polynuclear Aromatic Hydrocarbons

Toxicity factors are not available for a number of PAHs which are listed in Table C6. The Tier 1 values for these compounds were determined by multiplying the STARC value by a normalizing factor (relative potency factor, RPE) which relates the cancer-related toxicity of each compound to that of benzo(a)pyrene. To calculate site-specific STARC values for these PAHs, the site-specific value for benzo(a)pyrene should be calculated first using the site-specific parameters. This value should be divided by the factors in Table C6 to determine the STARC values for the listed PAHs.

**Table C6. Relative Potency Factors for Polynuclear Aromatic Hydrocarbons**

Contaminant	RPE	Contaminant	RPE
benzo(a)anthracene	0.15	chrysene	0.0044
benzo(b)fluoranthene	0.17	dibenzo(a,h)anthracene	1.1
benzo(k)fluoranthene	0.02	indeno(1,2,3-c,d)pyrene	0.055

### H. Total Petroleum Hydrocarbons

MDNR is aware of research efforts directed toward determining health-based criteria for TPH. The department is currently reviewing these efforts and evaluating the possibility of using health-based cleanup levels for TPH. However, this evaluation is not complete, therefore calculation of Tier 2 values for TPH is not yet possible. Tier 1 target values will apply to all sites until appropriate site-specific methods can be identified.

## 3. PROCESS FOR DETERMINING TIER 2 GROUNDWATER CLEANUP (GTARC) VALUES

Tier 2 groundwater cleanup standards have not yet been developed. Until these are available, the Tier 1 GTARC values in Table B1 should be used.